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AUTHOR Lederman, Norman G.; Latz, Mark
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ABSTRACT

The purpose of this longitudinal investigation was to assess the nature, development, and changes in preservice secondary science teachers' (n=12) conceptions/knowledge structures of subject matter and pedagogy as they proceeded through a fifth-year Master of Arts in Teaching (MAT) program. Open ended written questionnaires were used in Phase I of this investigation. Five subject matter questionnaires and five pedagogy questionnaires were completed over the span of the entire MAT preparation program. In Phase II, a 45-minute video taped interview was conducted. It appears that preservice science teachers do not have well formed and integrated subject matter or pedagogy knowledge structures. (PR)

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Emergence and Interactions of Knowledge Structures In the Preservice Teacher

Norman G. Lederman
Visiting Research Associate Professor
Graduate School of Science Education
National Changhua University of Education
Changhua, Taiwan 500

Mark Latz
Department of Science & Mathematics Education
Oregon State University
Corvallis, Oregon 97331

Paper presented at the Annual Meeting of the National Association for Research in Science Teaching Atlanta, Georgia, 1993

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Emergence and Interactions of Knowledge Structures In the Preservice Teacher

Interest in teachers' knowledge of subject matter has gained renewed emphasis as a consequence of current attempts to increase the quality of teacher education programs (Carnegie Forum, 1986; Holmes group, 1986; Kennedy, 1990) and the evaluation of teaching (Shulman, 1986; 1987). In many states, teacher education reforms have resulted in a significant increase in entry requirements, such as subject matter degrees and subject matter competency examinations (e.g., National Teacher Examination) for prospective teachers. Such changes in policy have been made in spite of the fact that prior attempts to relate quantitative oriented measures of what teachers know (e.g., GPAs, college credit hours, degrees attained) with measures of effective teaching have rarely produced relationships of strong, practical significance (Brophy & Good, 1986).

Historically, previous paradigms of research on teachers' knowledge and effectiveness have provided us with correlational data on quantitative measures of teachers' knowledge. However, this research has not provided us with the necessary information to answer current questions and concerns about the importance of one's subject matter knowledge. Consequently, researchers have recognized the need for more in depth qualitative measures of teachers' conceptual frameworks of subject matter in an effort to enlighten the discussion of teachers' subject matter knowledge, its formation, and its potential impact on instructional practice.

Recent attempts to explore teachers' conceptual understandings of subject matter have used a wide variety of approaches, notably including semantic networks, word associations, concept maps, and various versions of

card sort tasks (Baxter, Richert, & Saylor, 1985; Hashweh, 1986; Hauslein & Good, 1989; Hauslein, Good, & Cummins, 1992; West, Fensham, & Garrard, 1985; West & Pines, 1985; White, 1985; Wilson, 1989; among others). Although such approaches are often used in concert with interview protocols, respondents are typically asked to organize and/or categorize topics or themes provided by the researcher in order to unveil underlying subject matter structures. Additionally, methodological flaws such as assuming that a coherent and stable subject matter structure already exists and the short duration of investigations further call into question the results obtained thus far. Although the data yielded by the aforementioned techniques are qualitative in nature, the structure imposed on data collection arguably compromises the benefits and purpose of using a qualitative research design. To date, relatively few studies have avoided the pitfalls of limiting subjects' representations of content knowledge to an a priori list of topics while assessing development over time.

A notable exception has been Morine-Dershimer's (1989) open-ended assessment of preservice teachers' conceptions of lesson planning and subject matter structures during a microteaching course. Over the duration of the course these teachers adjusted their subject matter structures to be more consistent with what and how they taught. In similar investigations, Gess-Newsome and Lederman (1993) and Lederman, Gess-Newsome, and Latz (1992) assessed preservice science teachers' subject matter structures as they proceeded through a full academic year of subject-specific teacher preparation courses and their student teaching experience. The results indicated that the preservice teachers' subject matter structures were revised as a consequence of the act of teaching.

Although the development and role of subject matter knowledge within teachers' professional development is presently the source of much research and controversy, the parallel development and role of pedagogical knowledge, with few exceptions (Hoz, Tomer, & Tamir, 1990; Lederman, Gess-Newsome, & Latz, 1992; Morine-Dershimer, 1989), has yet to be systematically analyzed. Furthermore, the interaction and possible melding of these two domains of knowledge, as specified in Shulman's (1986; 1987) model of pedagogical content knowledge, remains an area of much needed research.

The purpose of this longitudinal investigation was to assess the nature, development and changes in preservice secondary science teachers' conceptions/knowledge structures of subject matter and pedagogy as they proceeded (as a cohort group) through a one year Master of Arts in Teaching (MAT) program In particular, this investigation attempted to answer the following questions: 1. What is the nature/appearance of preservice science teachers' subject matter and pedagogy knowledge structures? 2. What is the source(s) of these knowledge structures? 3. Are these knowledge structures stable during teacher preparation?, and 4. What is the relationship between these knowledge structures and how do they relate to the act of teaching?

Although there is general agreement that all individuals structure their knowledge in some manner, an exact definition of 'knowledge structure' remains elusive, with "the representation of relations between elements of memory" perhaps representing the original notion as used within science education (White & Tisher, 1986). For the purposes of this investigation, 'knowledge structure' refers to the knowledge an individual possesses and the manner in which this knowledge is organized. Our research definition is intentionally broad and it is recognized that we might be more accurate in describing our teachers' knowledge as "conceptions "(and at times we use the

terms synonymously) of subject matter and pedagogy as opposed to formal knowledge structures. Whether the label "knowledge structure" or "conception" is preferred, such referents should not distract the reader from the primary focus of this investigation: the nature, development, and changes in preservice science teachers' knowledge of subject matter and pedagogy as they proceed through a professional teacher preparation program.

Design

Sample

Twelve preservice secondary science teachers (seven biology, three general science, one chemistry, one physics; seven males, five females) were studied as they proceeded (as a cohort group) through a fifth year MAT teacher preparation program. These individuals constituted 75% of the total number of students (i.e., 16) enrolled in the program with the remaining four pursuing initial certification in mathematics. Each of the preservice teachers was seeking initial certification and each possessed at least a B.S. degree in his/her teaching field (five possessed M.S. degrees and one a Ph.D.). Consequently, these preservice teachers possessed a level of subject matter knowledge well above that of the typical preservice teacher. A summary of the sequence of courses and points of data collection is presented in Table 1.

Insert Table 1 Here

Given the nature and context of this research, it is important to provide some description of the critical aspects of the course work in which the preservice teachers were enrolled during the duration of the investigation The Methods/Practicum I (Summer Term) included instruction on the writing

of lesson plans and objectives, classroom questioning, teaching methods and strategies (other than laboratory and demonstrations), evaluation, and classroom management. Students were also given an opportunity to teach two mini-lessons (20 minutes) on a topic of their own choosing. The course in Educational Technology (Summer Term) focused primarily on the integration of computers and graphing calculators into instruction and as support for other teacher responsibilities. The Literacy and Communication course (Summer Term) focused on reading in the various content areas and study skills while the Educational Psychology and Introduction to Education courses were rather "traditional" in focus. The latter three courses included students from all MAT programs while the former two were restricted to those students pursuing science or mathematics certifications.

The Field Practicum and Seminar (Fall Term) placed the preservice teachers in actual classroom settings, beginning at the start of the public school year. Responsibilities were initially those of an instructional aid and culminated in full teaching responsibility for an instructional unit (approximately three weeks). Discussions of activities in the field were pursued during the weekly three-hour seminar associated with the practicum.. Additional seminar activities/assignments involved five action research projects, critical reviews of empirical research reports, and the development of a resource file. The Methods/Practicum II (Fall Term) included detailed discussions and modeling of laboratory and demonstration techniques, the nature of science, science-technology-society interactions, curriculum development, classroom management, cooperative learning, alternative assessment, and laboratory safety. The Microteaching practicum (Fall Term) served as an opportunity for the application and refinement of the methods and strategies discussed in the methods courses as well as an

opportunity to practice and revise lessons being planned for implementation in the Field Practicum. Each student was required to plan and teach four 20-minute lessons using the following methods/strategies: lecture/recitation, general inductive model (Joyce & Weil, 1992), general deductive model (Joyce & Weil, 1992), and "hands-on/laboratory." Lesson topics, chosen from those typically taught in the public schools, were randomly assigned for the lecture/recitation and deductive presentations. Due to the difficulty level of the teaching strategies and time constraints, students were allowed to select their own topics for the inductive and "laboratory" presentations. Lessons were videotaped and verbally critiqued by instructors and peers immediately following each lesson. Written critiques were provided by the course instructors (one week later) and a self-critique was completed by the presenter. Science Pedagogy (Fall Term) was more of a "share-a-thon" in which master teachers were invited to present/model classroom-tested activities. Debriefing discussions focused on the various uses of the activities and were intended to let the preservice teachers benefit from the master teachers' years of practical experience.

Student teaching (and a three hour weekly seminar) were completed during the Winter Term. During student teaching, the preservice teachers worked full time in a school setting and assumed full instructional responsibilities for 3-4 classes (two preparations). Full instructional responsibilities were assumed for a period of 10 weeks. The seminar primarily focused on the significance of events occurring in the various school settings and served as a mutual support group for the preservice teachers.

The Science Curriculum Practicum (Spring Term) systematically addressed current national curriculum reforms (e.g., NSTA Scope and Sequence, Project 2061,) and their relationship to statewide reforms. In

addition, each preservice teacher was placed in a community/business setting which was not specifically related to science or technology (e.g., supermarket, restaurant). A minimum of 10 hours per week were spent in the field setting and case studies were developed of situations and employees. These case studies were used in the campus-based portion of the course to facilitate discussion of the relevancy of curriculum and the completion of curriculum development projects. Science Pedagogy (Spring Term) was organized in the same manner as it was during the Fall Term.. Finally, the Introduction to Counseling course (Spring Term) was taught generically to students in all MAT programs and served to introduce the preservice teachers to foundational counseling principles and procedures.

It is important to note that there was no specific attempt to address or alter the preservice teachers' conceptions of pedagogy or subject matter in any way other than has been discussed in the presentation of the salient aspects of each course/practicum. Although space does not allow a complete description of each course/practicum/activity/assignment in the MAT program, an effort was made to include those aspects which would most likely influence the variables of concern in this investigation.

Data Collection and Analysis

The case study design specified by Bogdan and Biklen (1982), was considered most appropriate for this investigation. In this particular instance, the case study focused on a group of individuals who were all proceeded through the same teacher preparation program as a cohort group. Data was collected and analyzed in two phases. Of initial interest was whether preservice science teachers possess coherent conceptions/structures of their subject matter specialty and pedagogy. This question was addressed

primarily in **Phase I**. The additional questions proposed by this study were addressed in **Phase II.**

Phase I. Each subject was given approximately 30 minutes, on the first day of the Methods/Practicum I (Summer Term), to answer the following questions:

1. What topics make up your primary teaching content area? If you were to use these topics to diagram your content area, what would it look like?
2. Have you ever thought about your content area in the way you have been asked to do so above?

One day later, each subject was asked to answer the same questions, but with "important elements/concerns of teaching" substituted for the phrase related to primary teaching content area. The preservice teachers were asked to answer Question #1 again at the end of the Summer Term (in Methods/Practicum I), Fall Term (in Methods/Practicum II), Winter Term (in Student Teaching Seminar), and Spring Term (in Science Curriculum Practicum). For the second, third, fourth, and fifth questionnaire administrations, Question #2 was replaced with: "Have your views changed? If so, how and why?" A total of five subject matter questionnaires and five pedagogy questionnaires were completed. These assessments spanned the entirety of the MAT preparation program with the "posttest" diagram for a particular term serving also serving as a "pretest" for the subsequent term. The reader is again referred to Table 1 for a review of the data collection design and sequence of courses.

The preservice teachers were assured that there were no right or wrong answers to the questions about subject matter and pedagogy and that their responses would in no way affect their grade in a particular course or

progress through the program. Although 30 minutes was provided for the completion of each questionnaire, most students completed the questionnaire in 20-25 minutes. It should also be noted that no specific methods of formatting or organizing the subject matter and pedagogy "diagrams" were suggested to the preservice teachers. For instance, they were not asked to diagram their topics in the form of a concept map or hierarchical structure. However, the specific wording of the questionnaire remained a source of concern because there seemed to be no language alternatives which would not implicitly or explicitly direct the format and nature of the preservice teachers' responses. For example, the use of the words "topics" and "diagram" were seen as potentially undermining the intended flexibility of the questionnaire. Consequently, the oral instructions provided with the distribution of questionnaires emphasized our intent and associated language-use problem. In short, the preservice teachers were told that their descriptions of subject matter and pedagogy could focus on topics, themes, processes, strands, etc. and could be "represented" by use of a diagram, picture, description, or in any manner which felt comfortable.

Overall, it was felt that this methodology was superior to past attempts to assess subject matter and pedagogy knowledge structures because it gave respondents the freedom to select their own topics, themes, processes, strands, etc. (as opposed to card sorts) and to organize these elements of knowledge in any manner which felt comfortable (as opposed to artificially forcing representations into categories, hierarchies, dimensions, or particular formats). It was hoped that this approach would provide a clearer portrait of the preservice teachers' conceptions/structures of subject matter and pedagogy.

Qualitative analysis of the data collected during this phase attempted to derive any evident patterns among and within the preservice teachers' stated subject matter and pedagogy structures. This initial analysis (conducted by one of the researchers) served as a guide for additional data collection during a follow-up interview which occurred one week after the completion of questionnaire #5.

Phase II. Immediately following the end of Spring Term (and the completion of questionnaire #5) an attempt was made to assess changes in the preservice teachers' knowledge structures and to clarify any patterns elucidated in **Phase I**. Each subject was asked to participate in a 45-60 minute videotaped interview conducted by the same researcher who analyzed **Phase I** data. The interviews were guided by questions which asked the subjects to describe their current knowledge structures, discuss changes which had occurred during the year and any reasons for these changes, discuss any relationships between the knowledge structures or between either knowledge structure and their teaching, and their feelings about completing the questionnaire throughout the year. During the interview, the previously completed knowledge structure diagrams/representations (five for subject matter and five for pedagogy) were displayed and discussed individually and as a group. Finally, all subjects were given an opportunity to revise the diagram/representation produced for the final questionnaire to conform to any changes which might have occurred since its completion.

Importantly, the interview was also viewed as a means to compensate for any confusion created by the paper-and-pencil questionnaire (either with respect to the respondents' reactions or the researchers' interpretations. of responses). The problems associated with researchers' attempts to infer individuals' conceptions, knowledge, and beliefs solely from paper-and-pencil

measures has been well recognized (Lederman, 1992). All interviews were transcribed for analysis. Data were compared within and between individuals to derive any evident patterns for this particular group of preservice teachers. Both phases of data analysis were conducted by one of the researchers and later corroborated by independent and "blind" analyses performed on both written and videotaped data by the other researcher. In particular, the other researcher analyzed both the written and interview data in the same manner as performed by the primary researcher, searching for any evident patterns in the responses provided across time within individuals and between individuals. This procedure allowed for a richer understanding and interpretation of the preservice teachers' conceptions of subject matter and pedagogy. The differing perspectives of the researchers provided for a more comprehensive interpretation of data while at the same time "protecting" interpretations from being overly influenced by the particular perspective of a single researcher (Bogdan & Taylor, 1975; Lederman & Gess-Newsome, 1991; Lincoln & Guba, 1985; Miles & Huberman, 1984).

Results and Discussion

The results reported represent the culmination of several rounds of data analysis, by each of the two researchers, and will be organized in terms of the initial questions guiding the investigation.

What is the nature/appearance of preservice science teachers' subject matter and pedagogy knowledge structures?

Interview responses indicated that the preservice teachers were quite hesitant while completing the first (and sometimes the second) subject matter questionnaire. Many felt tentative or uncertain about what to write. They indicated that there was no problem understanding the question or task at

hand, but rather they were hesitant about the content (and quality) of their responses as indicated by the following representative comments:

> "I understood what was wanted and I also knew that it would not affect my grade. But still, I always wonder about anything I put down on paper. I did not want it to look like I don't know my subject matter."

> "I mean, I know my subject matter just fine. It was easy to put it all down. But, deciding how it all fits together or if it fits together, I never really thought about it before or needed to think about it before."

> "I know what you said, but I didn't want to do badly in showing what I think I know."

In short, the preservice teachers were concerned that the questionnaire was a test of their subject matter understanding. No similar hesitancy or concern was expressed with respect to any of the administrations of the pedagogy questionnaire. For example, two of the preservice teachers noted:

> "I had no problems with the pedagogy questionnaire. Teaching is pretty straight forward in terms of what you need to know."

> "After going to school all of these years, I better have some idea of what teaching is about."

Overall, the subject matter conceptions/structures were primarily listings of discrete topics/science courses taken at the university and the pedagogy structures were primarily listings of the teacher oriented components of instruction with student oriented components (such as motivation, prior knowledge) given little or peripheral emphasis. The presence of integrative themes or connections between or within the components of either subject matter or pedagogy structures was not common. Indeed, integrating curriculum themes (such as the nature of science) were only found in two of the preservice teachers' representations. The significance of these notable exceptions is discussed later. Again, it is important to note that the oral instructions provided with the questionnaires explicitly emphasized that the word "topics" need not be taken literally and that respondents could feel free to include topics, themes, processes, strands, etc. In addition, it was also emphasized that representations need not be "diagrams" and could take whatever form most accurately portrayed each individual's conceptions.

Organizational patterns were quite traditional with respect to subject matter. In general, subject matter structures were presented in three general formats: discrete (Figure 1), simple hierarchy (Figure 2), web-like (Figure 3). Naturally, the labels used to describe the appearance of subject matter representations were a matter of convenience. Of more significance are the clear distinctions among the representations as opposed to the descriptive-labels.

Insert Figures 1, 2, 3 Here

Pedagogy structures tended to be organized as discrete "listings" of teacher focused responsibilities and instructional approaches (Figure 4) or web-like/interrelated representations of concerns, knowledge, and/or activities performed (Figures 5 & 6) , with students conspicuously absent from the primary focus. Again, descriptive labels are of convenience and should not distract from the clear visual and substantive distinctions among representations.

Insert Figures 4, 5, & 6 Here

What is the source(s) of these knowledge structures?

When asked about the source of their subject matter structures, many students admitted, as might be expected, that the portrayed elements and organizational scheme came from college courses and that the representations were only tentatively delineated without any conscious rationale. For example, comments consistent with the following were common:

> "I really have nothing to go by other than what I have read and heard in my biology classes."

> "I do remember that we discussed 'what is science' or 'what is chemistry' at the beginning of some of my classes. That plus what was in the class is what I put down."

> "This is really strange. I never specifically thought about physics as a whole. I just figured physics was physics and since I have done pretty good in physics, I figure I know what it is."

These findings suggest that preservice science teachers are not being presented with an overt or covert structure (or global conceptual framework) of subject matter (or at least one that is recognized) as part of their content preparation. The reader is also reminded that these preservice teachers were required to take an additional nine credit hours of graduate work in their subject matter specialties as part of the MAT. Consequently, the lack of any recognizable subject matter structure is not unique to undergraduate level subject matter courses. Given the disconnected and fragmented manner in which college science courses are taught and presented (Cheney, 1990) the results here are not very surprising. Unfortunately, this fragmented and discrete style of content presentation may be passed on, intact, as these preservice teachers attempt to teach courses at the secondary level.

When asked about the source of their pedagogy knowledge structures, the preservice teachers uniformly referred to introductory education courses and personal experiences as a student:

> "Pedagogy is what we have been talking about in our education and science education courses, isn't it?"

> "I have been a student for over 20 years. What I wrote was what I picked up from my experience."

> "I don't mean to minimize the importance of pedagogy. I always hated that word. Why don't they just call it teaching? Anyway, teaching seems pretty straight forward to me. What we discuss in class is what I've already figured out from being a student."

When students were asked if they had ever thought about their subject matter specialty or pedagogy in the manner requested by the questionnaire, only one of the 12 preservice teachers (the Ph.D.) admitted having previously thought of his subject matter in this manner. None admitted having done so for their knowledge of pedagogy. Contrary to the findings of previous research which has relied on card sort tasks and other restrictive assessment procedures (Baxter, et. al., 1985; Hashweh, 1986; Hauslein, Good, & Cummins, 1992; Hoz, et.al., 1990; Wilson, 1989), but consistent with research using more open-ended assessments (Lederman, Gess-Newsome, & Latz, 1992), these preservice teachers, appeared to possess no coherent or carefully considered structure for subject matter. Furthermore, the topics, themes, etc. used in the representations by this group of preservice teachers exhibited little resemblance to the a priori elements/topics used in previous investigations. Perhaps, the more directed approaches (e.g., card sort tasks, semantic maps) used in previous investigations of subject matter structures served to create the resulting structures (with respect to both content and organization) as opposed to providing an objective assessment. With respect to pedagogy, the results of this investigation were consistent with those obtained in previous investigations (Lederman, Gess-Newsome, & Latz, 1992; Morine-Dershimer, 1989).

Are these knowledge structures stable during teacher preparation?

Although changes were clearly noted in the pedagogy knowledge structures by the third questionnaire administration, subject matter representations remained relatively stable. Only one of the preservice teachers indicated significant changes in his subject matter representation. The lack of change in subject matter conceptions in response to the planning and implementation of lessons (in microteaching or field settings) is a finding

which contradicts an emerging, but consistent body of literature (e.g., Hauslein, Good, & Cummins, 1992; Gess-Newsome & Lederman, 1993; Lederman, Gess-Newsome, & Latz, 1992). When asked to discuss their conceptions of subject matter during the interview, typical responses clearly reinforced the impression provided by the written representations.

> "My views haven't changed much. Maybe I have expanded some things a bit, but nothing I would call really different."

> "Nothing has happened in any of the classes I am taking to cause me to reconsider anything. I'm not sure one or two classes in biology would be enough for me to change anything."

The interviews definitively indicated that these preservice teachers had not altered their views of subject matter. Furthermore, those who speculated about potential sources of change did so in the context of additional subject matter courses with no references made to any possible effects created by how the subject matter was used. In response to these surprising results, the preservice teacher with a Ph.D. (the last individual interviewed) was directly asked if he thought his view of geology could or would be changed as a result of his teaching geology/earth science. His response was strong and left little room for misinterpretation:

> "Why should my views about geology or science in general be be altered by teaching? I'm an unapologetic advocate of the material and imparting my interest to students, rather than teaching for teaching's sake alone."

Clearly, this individual possesses strong feelings about his subject matter and his comments seem to indicate that although his views of subject matter may influence classroom instruction, the reciprocal influence of the act of teaching on his views is not considered as a possibility.

Pedagogy representations became increasingly more complex during the duration of the investigation. A proliferation of student focused components (e.g., motivation, learning styles, relevancy, etc.) as well as additional teacher roles (e.g., friend, counselor) and responsibilities were clearly evident. Of most significance was a general shift away from linear representations of pedagogical knowledge to more web-like frameworks which placed the students and their concerns at the center (Figures 7 & 8). For example, the individual who created Figure 7 had initially created Figure 5.

Insert Figures 7 & 8 Here

In general, representations of pedagogy appeared to be influenced by the planning and implementation of actual lessons. A common explanation for the change in the preservice teachers' pedagogy structures is illustrated by the following comments:

> "With the students there, you can't do anything but attend to their needs. Their concerns become much more important than yours whether you like it or not."

> "All the time you spend on planning takes a back seat to the students once the bell rings. The students must be at the center of everything you even consider doing."

Of course it is possible that, although students were given little if any visible emphasis in the preservice teachers' initial pedagogy representations,

students as the focal point of one's considerations was an understood reality and did not need to be explicitly indicated in one's representation. The preservice teachers' perspective on whether and why students became a focal point in the pedagogy structures is best typified by the following comment made during a discussion of pedagogy structure #1:

> "How could I have known the importance of students to all of this? I hadn't seen one yet."

In short, the preservice teachers reinforced one of the commonly voiced shortcomings of campus-based teacher preparation courses. Interestingly, however, the quick revision of these preservice teachers' pedagogy structures to include students' as a focal point in response to actual teaching is consistent with prior research and again calls into question Fuller's (1969) developmental model of teachers' concerns. The results here and elsewhere (Gess-Newsome & Lederman, 1993; Lederman & Gess-Newsome, 1991) appear to indicate that preservice and beginning teachers quickly develop concerns for students as soon as they are immersed in classroom teaching and the "shift" in concerns is more an artifact of the "sterility" of campus-based courses than a developmental process.

What is the relationship between these knowledge structures and how do they relate to the act of teaching?

During the interview the preservice teachers were asked to discuss and relate the set of 10 representations (five subject matter and five pedagogy). Whenever overlaps or similarities between the two types of structures were noted, the subjects were asked if they could be combined into one diagram or whether a combined depiction would be more accurate. The preservice teachers uniformly responded negatively:

> "Not really. I would rather keep them separate. Subject matter knowledge and pedagogy are definitely different in my mind."

> "It is important to keep the two separate in your mind. When you are teaching, sometimes you need to be focusing on the subject matter and how it is related and at other you need to focus on the best approach to promote learning."

The preservice teachers clearly expressed the belief that pedagogy and subject matter knowledge were separate entities which were applied in an integrated manner during teaching. During the interview, individuals were provided with a hypothetical teaching situation in which students are unable to understand a particular aspect of subject matter. When asked about what their response would be, the preservice teachers typically described their decision making process as essentially involving two types of knowledge:

> "My knowledge of teaching is especially important here because it allows me to approach the content using a different approach. Different students learn in different ways and the expert teacher is capable of successfully using a variety of techniques. My subject matter knowledge allows me to come at things from different ways and to focus students' attention on the most important points."

Pedagogical knowledge was considered to be at work during the decision to try a different approach and the implementation of that approach, while subject matter knowledge was considered to be involved by providing the flexibility to present content in a different manner. Additionally, the preservice teachers clearly expressed the belief that pedagogical knowledge was the more important for making instructional decisions:

> "I was most surprised by how little high school students know. This quickly made me realize that my knowledge of teaching would make me successful and not my knowledge of subject matter."

> "The students will have plenty of opportunities to learn the subject matter. Students' needs are more important than anything else. When I am making decisions on my feet, I rely on my knowledge of students, their needs, and my teaching skills."

As mentioned, the preservice teachers did not alter their conceptualizations of subject matter knowledge in response to their exposure to public school students and the planning and implementation of science lessons. This finding does not support prior suggestions (Hauslein & Good, 1989; Hauslein, Good, & Cummins, 1992) that it may be impossible to view subject matter as separate from the manner in which it is, or will be used. The act of teaching and/or thinking about how one will teach subject matter did not appear to have a significant influence on the way that subject matter was conceptualized among this group of preservice teachers.

Pedagogy structures were seen to shift toward a focus on student concerns at the same time the preservice teachers were actively involved in the planning and implementation of lessons. This finding is consistent with assertions made by Lederman and Gess-Newsome (1991) concerning the shift in concerns of preservice science teachers toward students as soon as they begin to conduct lessons in actual field settings.

When specifically asked if their stated subject matter and pedagogy knowledge structures were evidenced in their teaching, either microteaching lessons at the university or lessons in actual field settings, the preservice

teachers were confident that each of the knowledge structures (with two notable exceptions related to subject matter structures) was reflected in how and what they taught:

> "Without a doubt! How could it be any other way? I teach biology in the same way I view biology. The interactions on my diagram are the same ones I try to make in the classroom ---sometimes in a single lesson and sometimes within several lessons."

> "As I said and drew, students are the most important which must be considered. In my lessons, regardless of topic, students are clearly my central concern."

These results are consistent with a large body of literature on the relation of subject matter structures and teaching (e.g., Baxter, et. al., 1985; Hashweh, 1986) and contradicts recent research (Gess-Newsome & Lederman, 1993; Hollingsworth, 1989) which indicated that preservice teachers are too overwhelmed by day-to-day instructional responsibilities to adequately and consciously incorporate integrated subject matter structures into daily instruction. However, the present results concerning the translation of subject matter and pedagogy knowledge structures into classroom practice must be interpreted with extreme caution. The discrepancies between teachers' self-reports and actual classroom practices has been well documented. Additional research of this nature which includes actual classroom observations should be pursued.

Implications for Science Education

It does not appear that preservice science teachers have well formed and integrated subject matter or pedagogy knowledge structures. Consistent

with previous research (Gess-Newsome & Lederman, 1993; Hauslein, Good, & Cummins, 1992; Lederman, Gess-Newsome, & Latz, 1992), the knowledge structures which do exist are largely the result of college course work and are often fragmented and disjointed with little evidence of coherent themes. With respect to subject matter structures, the perennially popular policy of requiring increased subject matter backgrounds for preservice teachers may not be an effective approach for the improvement of science instruction. One only needs to consider the nature of the subject matter representations which this group of preservice teachers derived from their science course work. Furthermore, the preservice teachers investigated in similar investigations (Gess-Newsome & Lederman, 1993; Lederman, Gess-Newsome, & Latz, 1992) possessed far less extensive backgrounds in science and were noted to develop more integrated subject matter structures in response to the planning and implementation of instruction. It is possible that the more extensive academic backgrounds, as exhibited by the preservice teachers in the present investigation (which is consistent with current teacher preparation reforms), may result in the development of more firmly entrenched and inflexible conceptions of subject matter. Consequently, although few would argue with the desirability of science teachers with extensive academic backgrounds, it might be that present approaches to college level science instruction promote the development of relatively inflexible cognitive structures which are at odds with the integrated framework required for the implementation of current curriculum reforms. Although possessing a relatively static view of one's subject matter as a consequence of more extensive academic background is a problem in need of solution, the situation is further exacerbated if the nature of the structure is less than desirable. Since any significant reform in the instructional approach which currently typifies college science teaching

seems unlikely, the responsibility of stimulating students to reflect on their subject matter (in an effort to promote the development of more integrated knowledge structures) seems to be most appropriately placed within the domain of the science educator. It is possible that repeated opportunities to reflect on one's subject matter (as it is being learned) may be sufficient to provide preservice teachers with a coherent schema for their subject matter and allow them to integrate more of the information presented in their science courses.

The inability of the preservice teachers to present a coherent conceptualization of pedagogy during the initial administrations of the questionnaires is not surprising. As prior research has indicated (Lederman & Gess-Newsome, 1991), a well formed pedagogy knowledge structure should not be expected without actual experience with "real" secondary students. Other than simply increasing the length of field experiences (as many teacher education programs are already doing), it may be necessary to provide increased opportunities for preservice teachers to conduct systematic classroom observations (Good & Brophy, 1991) and reflect upon instructional sequences.

Keeping in mind that classroom observations of these preservice teachers were not performed, the self-reported influence of preservice teachers' subject matter structures on classroom practice is consistent with much of the research on pedagogical content knowledge (Gudmunsdottiir & Shulman, 1987; Hashweh, 1986; Shulman, 1987). However, the resolve of these preservice teachers concerning the separate application of subject matter knowledge and pedagogical knowledge to instructional decisions is at odds with the current view that pedagogical content knowledge constitutes a separate domain of knowledge. It should not, however, be forgotten that the

subjects of this investigation were preservice teachers. Perhaps, the level of one's experience is directly related the interaction, and possible melding, of the two knowledge domains. It is intriguing to speculate that one's ability (or tendency) to mentally compartmentalize the two knowledge structures constitutes an indirect measure of pedagogical content knowledge. That is, with the benefit of experience and continual use of one's subject matter structure for purposes of teaching, the division between pedagogical knowledge and subject matter knowledge may become blurred. As one develops increased levels of pedagogical content knowledge, the ability or tendency to separate knowledge domains may be diminished. Research which compares expert and novice teachers' separation (or lack of separation) of pedagogical and subject matter knowledge is needed. Of additional interest is the elevated status given to pedagogical knowledge by the preservice teachers in making instructional decisions. This finding appears to be consistent with much of the research on problem solving (Chi, Feltovich, & Glaser, 1981) which indicates that individuals possessing expert knowledge approach problems (which are based upon such knowledge) differently from novices. It is reasonable to assume that classroom decisions are primarily pedagogical problems which necessarily require access to pedagogical knowledge as opposed to subject matter knowledge. Clearly, research which compares the pedagogy structures of experts and novices, as well as the relationship of these structures to classroom practice and instructional decisions needs to be pursued.

The apparent ease with which subject matter structures were translated into classroom practice, as reported by this group of preservice teachers, contradicts the findings of Gess-Newsome and Lederman (1993). The subjects in their research included global, integrative (and arguably

abstract) curriculum themes such as the nature of science and science-technology-society interactions in their subject matter structures. Such themes were virtually absent (with two notable exceptions) from the representations of the preservice teachers in this investigation, rendering the knowledge structures to be relatively simple by comparison. Consequently, it is quite possible that the ease with which a subject matter structure affects classroom practice (if at all) is as much a function of the relative complexity of the knowledge structure as it is related to curriculum constraints, administrative policies, management concerns, etc. The reader is reminded that two of the preservice teachers were exceptional in their inclusion of integrative curriculum themes such as the nature of science and science-technology-society interactions within their subject matter representations (e.g., see Figure 9).

Insert Figure 9 Here

These individuals were also the only two claiming that their subject matter conceptualizations were not readily evident in classroom practice. Thus, the data concerning the subject matter structures of these two preservice teachers further support the aforementioned assertion concerning the significance of knowledge structure complexity in relation to instructional translation. Indeed, when asked whether his subject matter structure was evident in his teaching, the individual who created the representation in Figure 8 replied:

> "You have to be kidding. I have too many other things to worry about, like who is hitting who, to think about how

to do anything other than presenting the required material quickly enough before they get bored."

Given that data concerning translation of subject matter conceptions/structures into classroom practice was self-reported in nature, additional research which includes direct classroom observations should focus on the relationship between knowledge structure complexity and classroom practice. The complexity of one's knowledge structure is especially critical since many of the new reforms in science education seem to depend on the incorporation of highly integrative themes such as the nature of science and science-technology-society interactions. It may be that reforms in science education depend on the development of subject matter structures which are exceedingly difficult for anyone other than an expert teacher to translate into classroom practice.

In light of the currently and widely accepted constructivist perspective on teaching and learning, a word of caution concerning research on knowledge structures seems to be in order. It would appear that current curriculum reforms are consistent with knowledge structures of a particular nature (i.e., highly integrated) and the authors of the volumes of emerging research concerned with pedagogical content knowledge also appear to place high value on integrated knowledge structures. However, we must ask the critical question of whether it makes sense to expect, or desire, that science teachers possess a knowledge structure (of subject matter or pedagogy) of a particular nature. Or, is it possible and desirable to promote knowledge structures (in preservice and inservice teachers) which are similar at some global level but capable of accommodating the recognized idiosyncratic nature of cognitive structures? Let us not impose a perspective which is as

restrictive as that of the "process-product" tradition on a line of research which has such enormous potential for the improvement of science instruction. Finally, future research must focus on questions related to the relative effectiveness of differing knowledge structures and whether teachers' knowledge structures truly impact on student learning.

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Table 1
Course Sequence and General Data Collection Design

Term	Courses/Practica (credits)	Data Collected
Summer	Methods/Practicum I (3) Educational Technology (3) Educational Psychology (3) Literacy and Communication (3) Introduction to Education (3)	Questionnaire #1 (start of term) Questionnaire #2 (end of term)
Fall	Field Practicum and Seminar (6) Methods/Practicum II (3) Microteaching (3) Science Pedagogy (2) Subject Matter Elective (3)	Questionnaire #3 (end of term)
Winter	Student Teaching & Seminar (15)	Questionnaire #4 (end of term)
Spring	Science Curriculum Practicum (5) Science Pedagogy (2) Introduction to Counseling (3) Subject Matter Electives (6)	Questionnaire #5 (end of term) Interview (end of term)

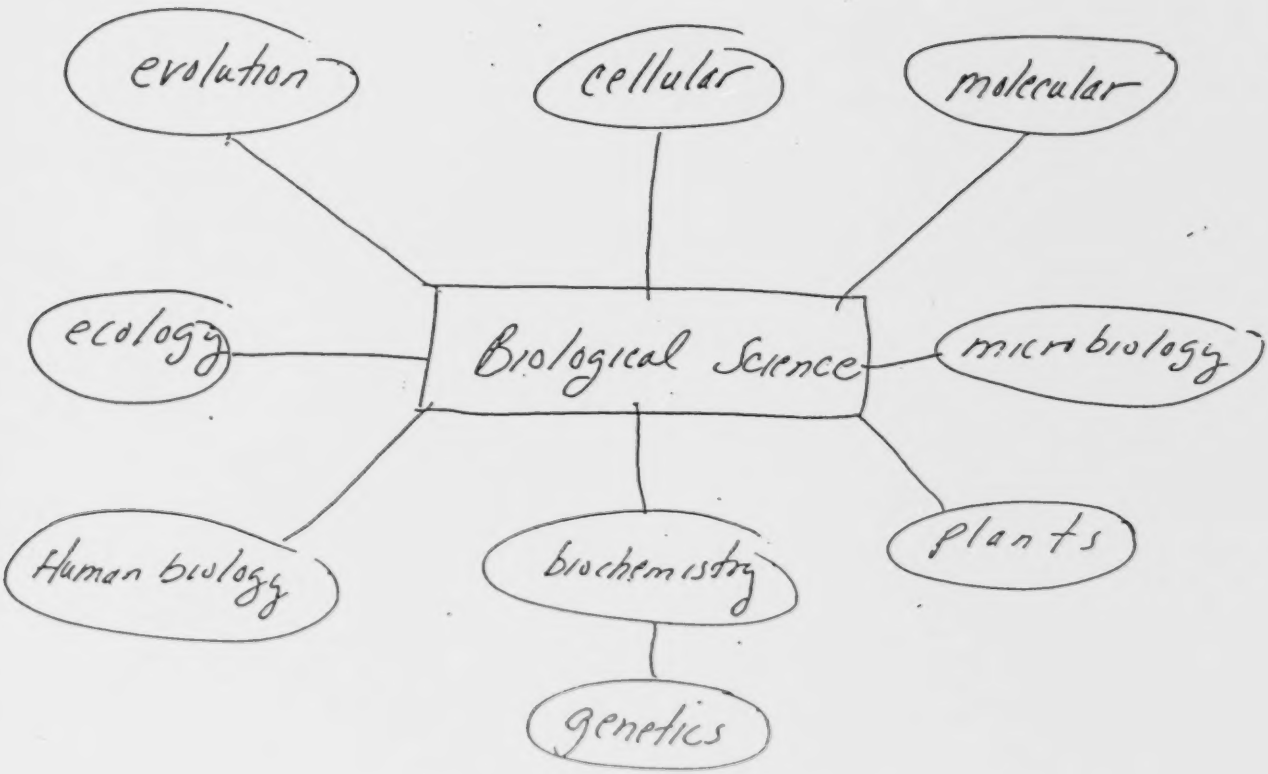

Figure 1. Discrete topics/course format for subject matter structure.

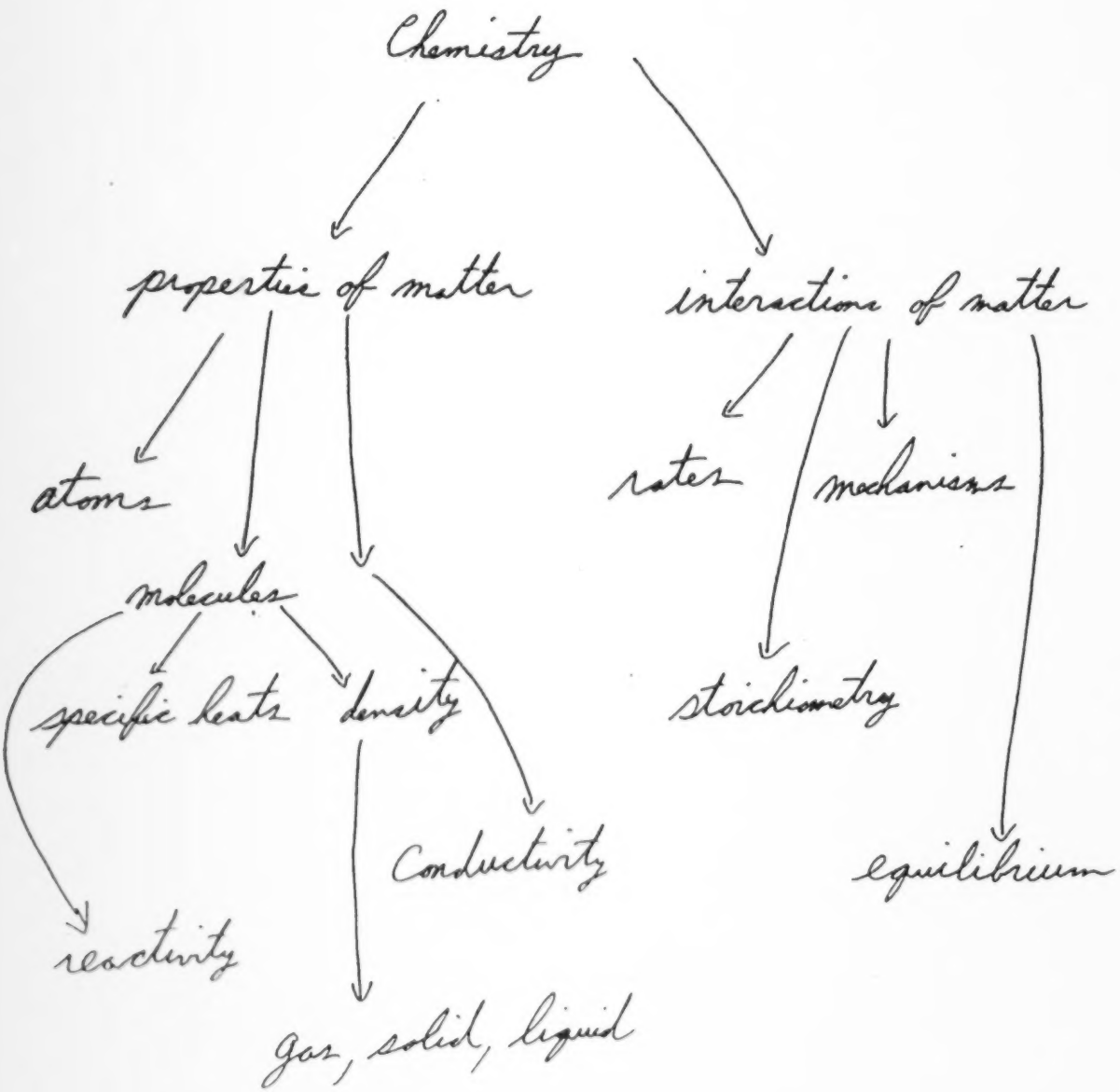

Figure 2. Simple hierarchy format for subject matter structure.

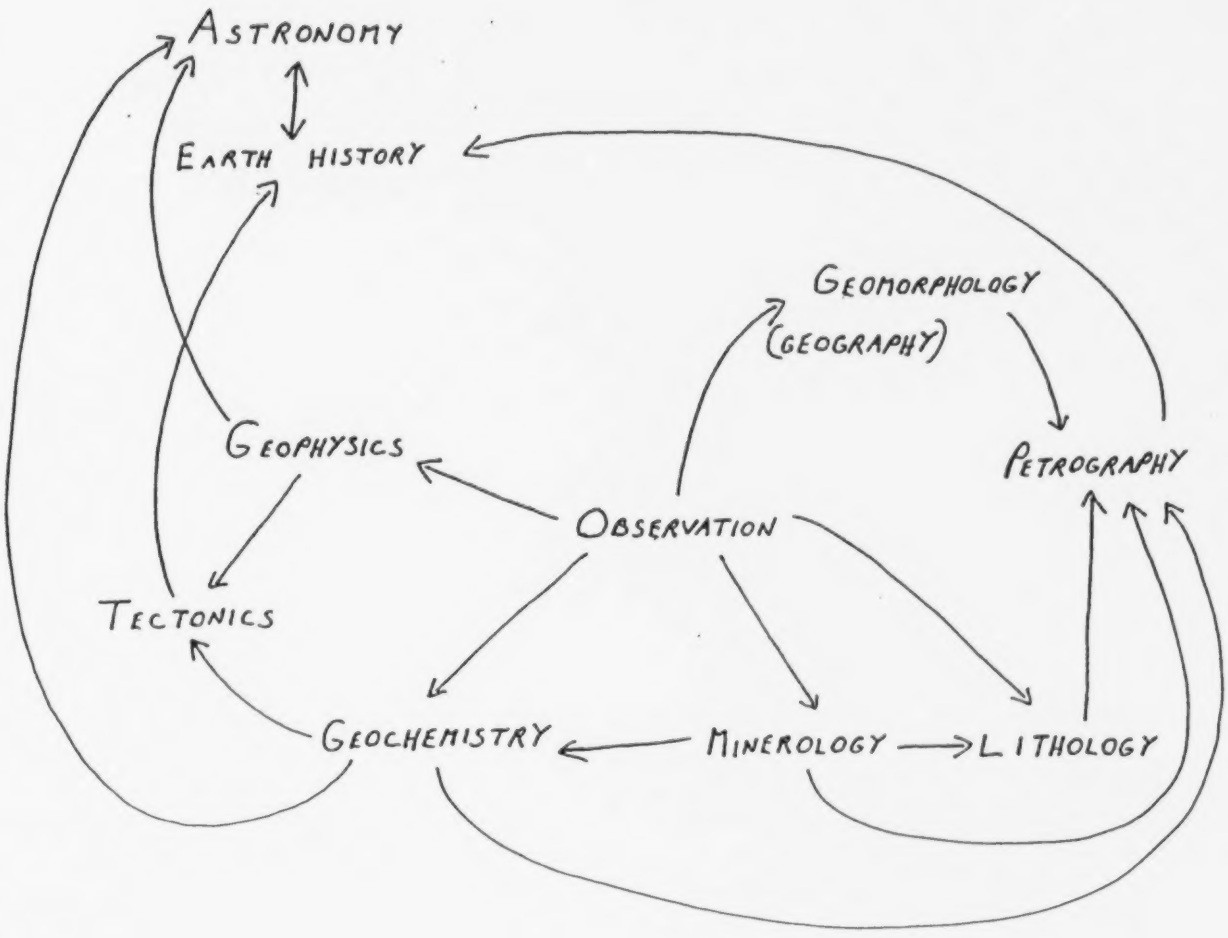

Figure 3. Web-like/interrelated format for subject matter structure.

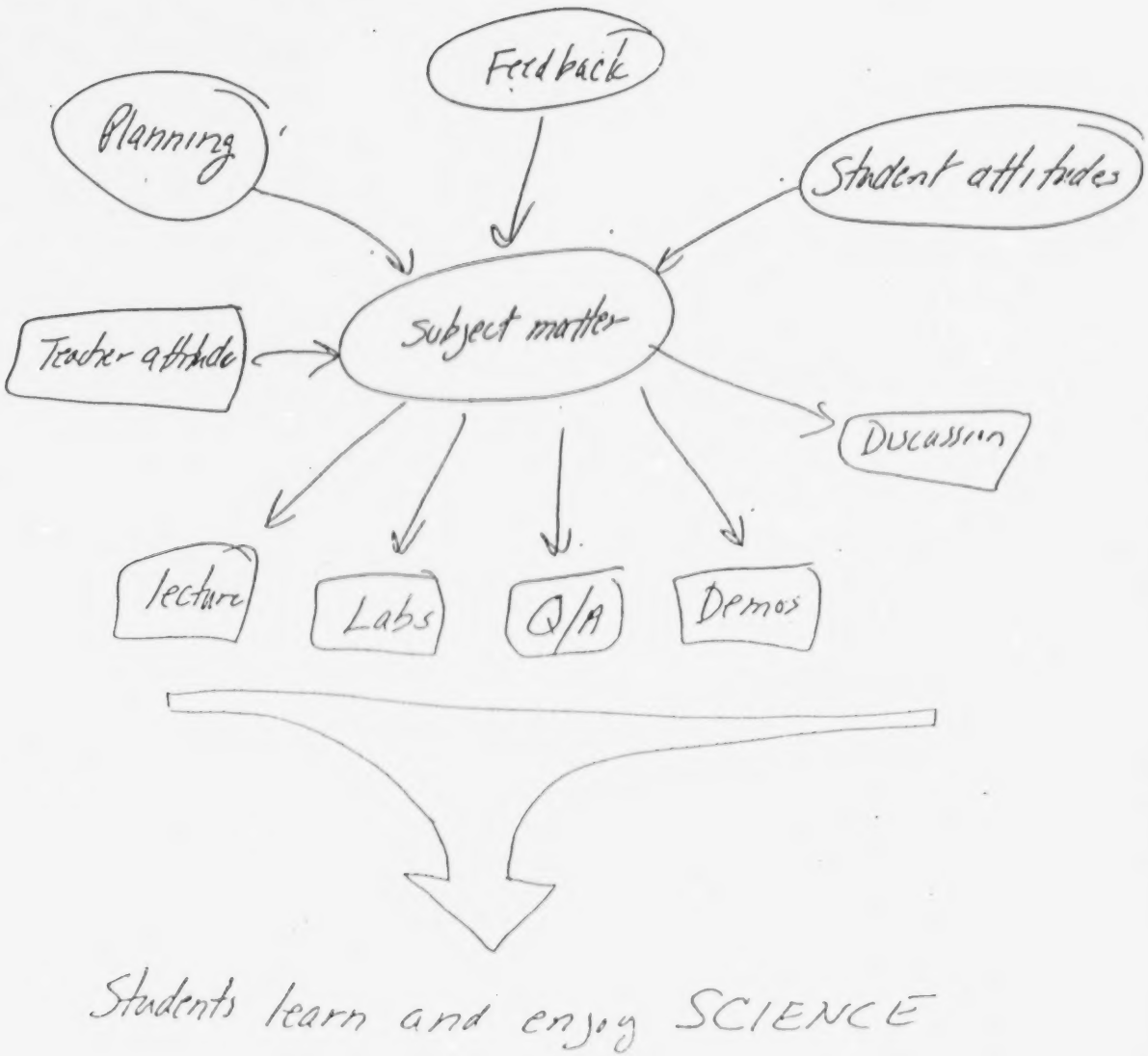

Figure 4. Discrete responsibilities/activities format for pedagogy structure.

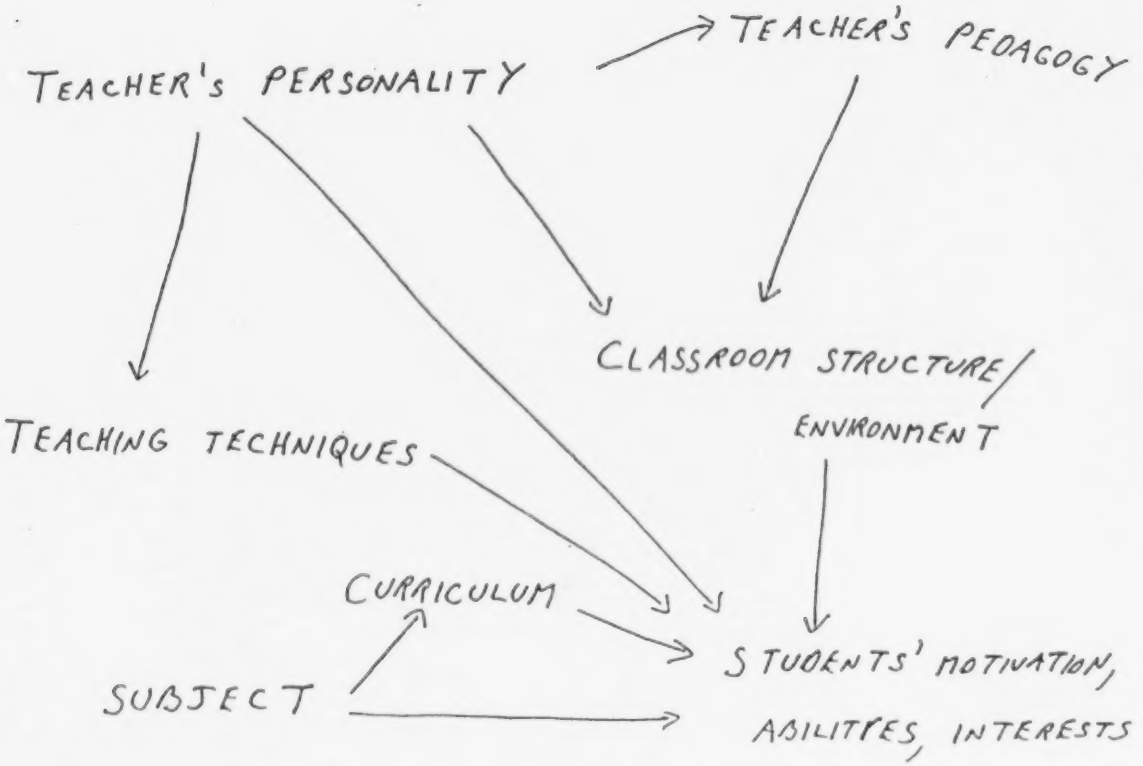

Figure 5. Web-like/interrelated format for pedagogy structure.

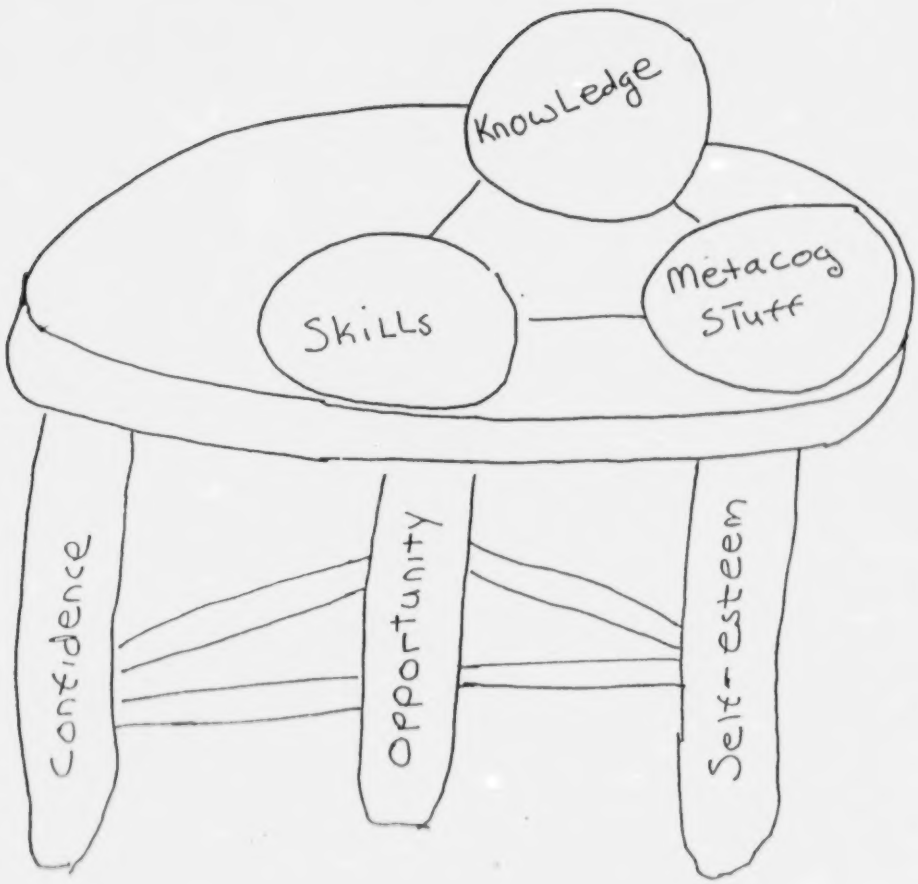

Figure 6. Web-like/interrelated format for pedagogy structure.

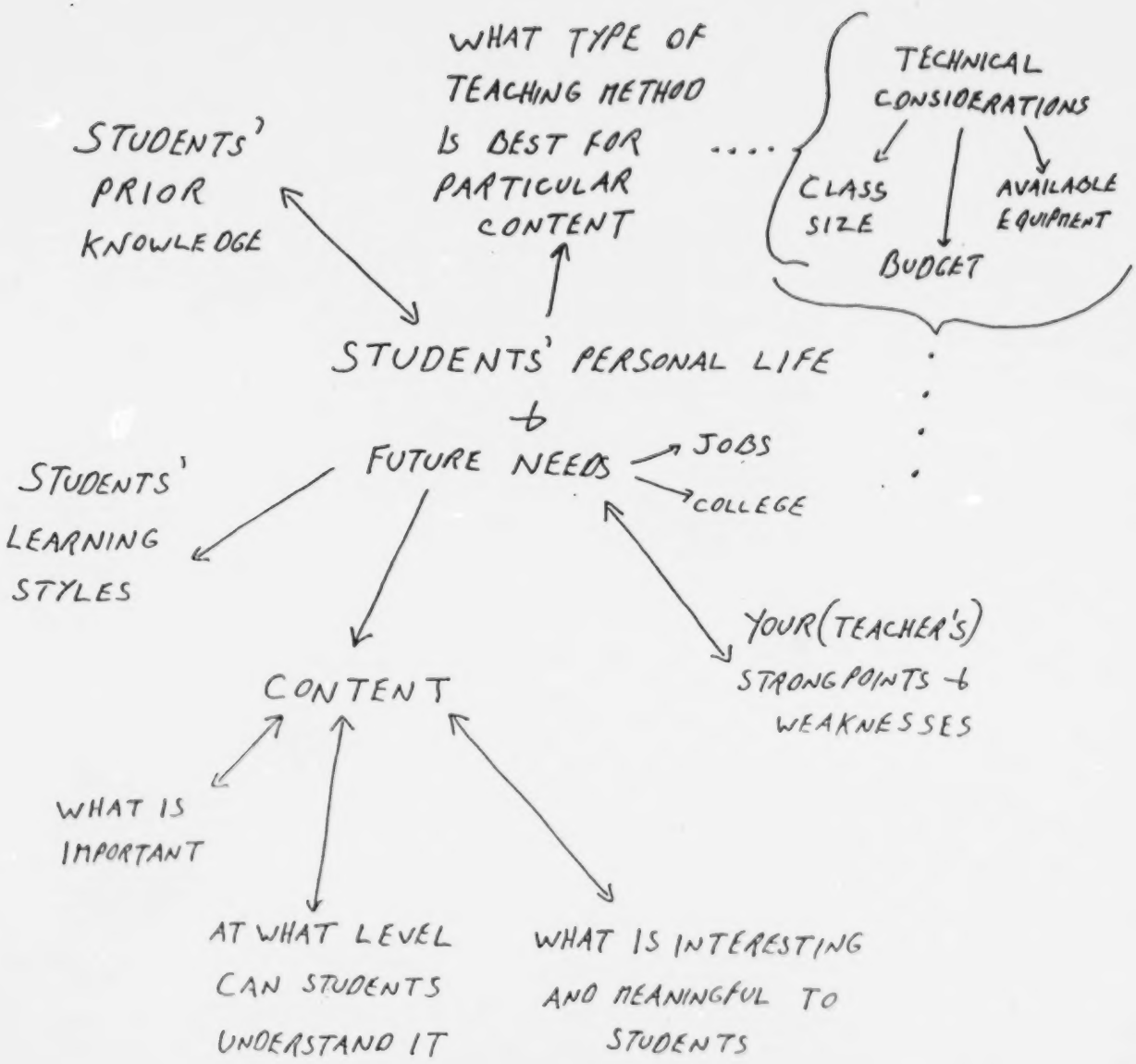

Figure 7. Representative diagram of student-centered pedagogy structure upon completion of MAT program.

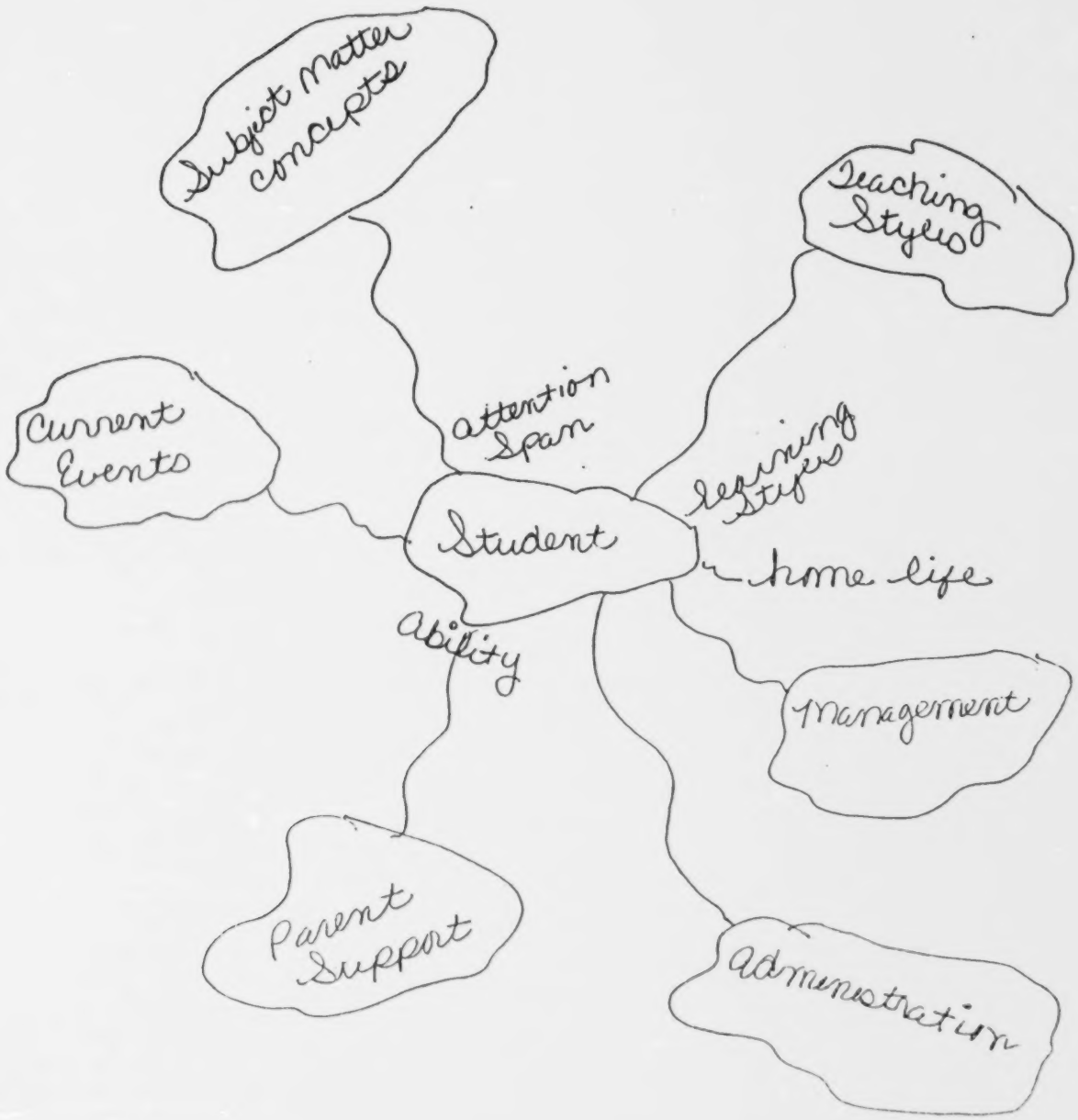

Figure 8. Representative diagram of student-centered pedagogy structure upon completion of MAT program.

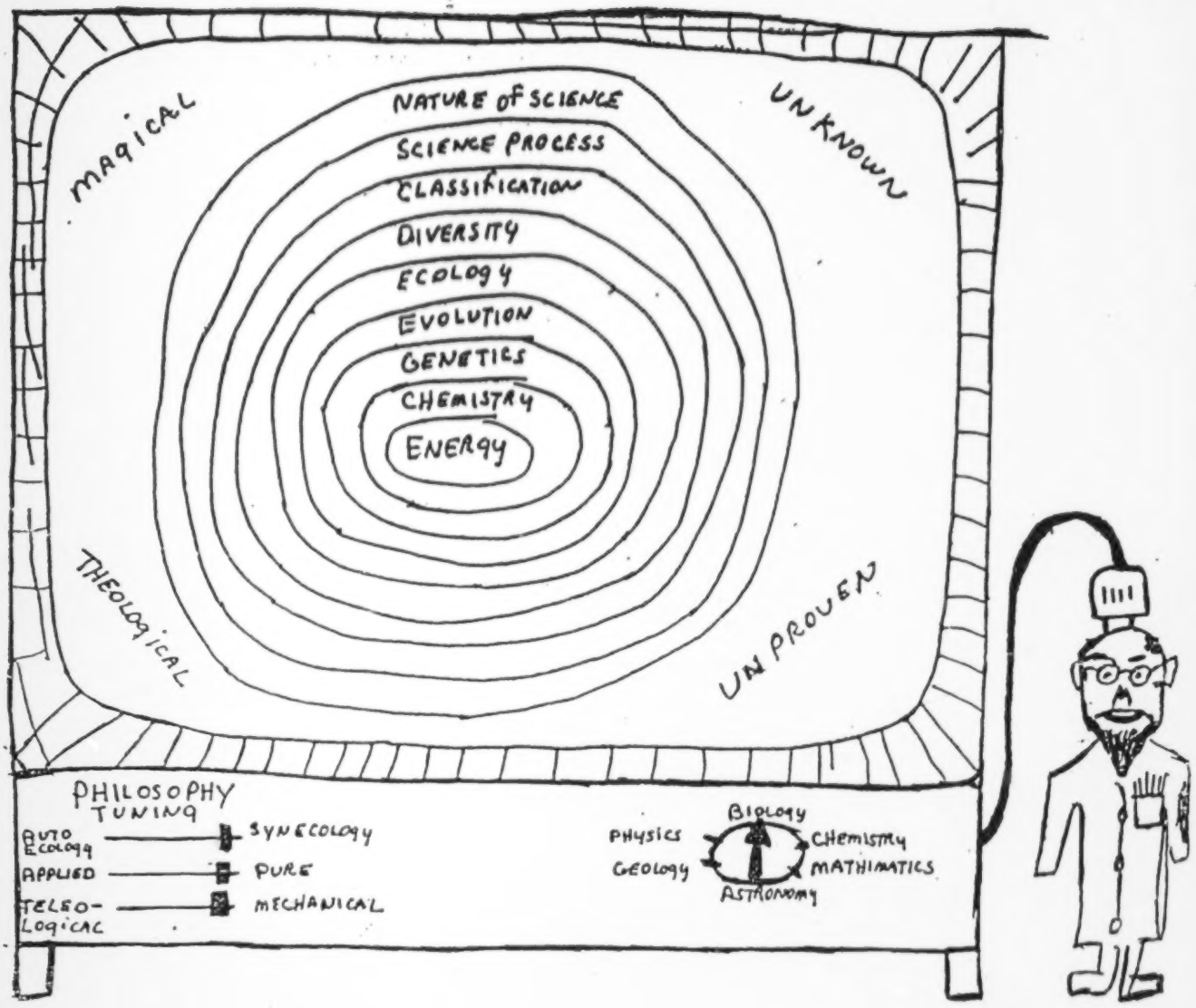

Figure 9. Subject matter structure with integrative curriculum themes.